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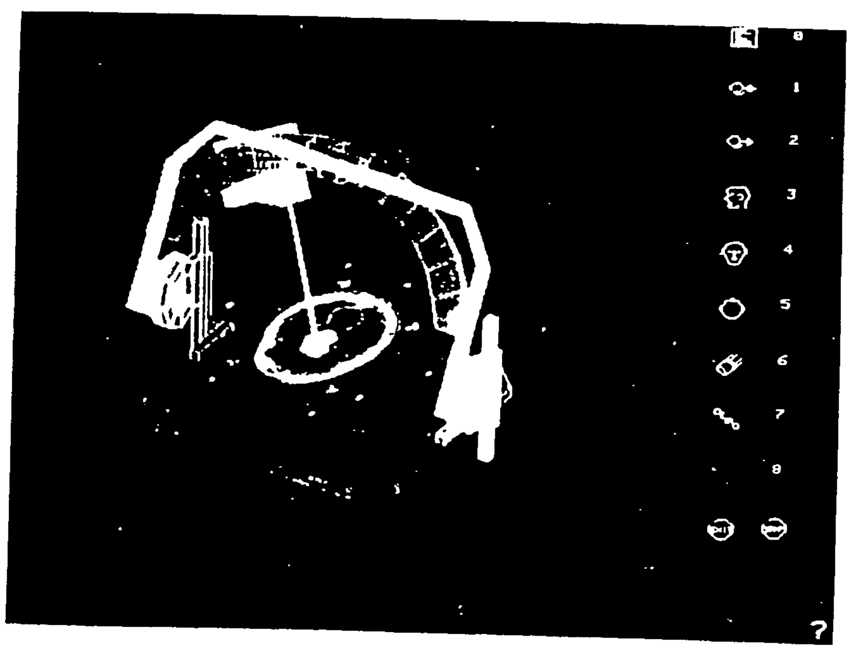

(57) Abstract

The disclosure is directed to the combination of actual imaging data with simulated graphics to provide a two-dimensional composite display, such as on a computer screen display, of a three-dimensional relationship between actual images and simulated images. The apparatus and method of the invention are useful for medical applications, particularly stereotactic procedures.

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THREE-DIMENSIONAL GRAPHICS SIMULATION AND ACTUAL IMAGING DATA COMPOSITE DISPLAY

CROSS-REFERENCE TO A RELATED APPLICATION

This application is a continuation-in-part application of U.S. Patent Application Serial No. 07/290,316, entitled *Method and Apparatus for Video Presentation from a Variety of Scanner Imaging Sources*, to Tyrone L. Hardy, filed on December 23, 1988, further filed as Canadian Patent Application Serial No. 612,019, filed on September 19, 1989, and U.S. Patent Application Serial No. 07,428,242, entitled *Three Dimensional Laser Localization Apparatus and Method for Stereotactic Diagnoses or Surgery*, to Tyrone L. Hardy, et al., filed on October 27, 1989, the teachings of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention (Technical Field):

The present invention relates to an apparatus and method for combining real or actual three-dimensional scanning or imaging data with simulated graphics so that the three-dimensional nature of structures within a given area or region, such as a head, can be viewed in relationship to the original image data.

Description of the Related Art Including Information Disclosed under 37 C.F.R. §§1.97-1.99 (Background Art):

There are primarily two methods in the art for three-dimensional (3-D) medical image simulation using various diagnostic scanning techniques, *e.g.*, magnetic resonance imaging (MRI) or nuclear magnetic resonance (NMR) imaging, computer tomography (CT), various isotope imaging techniques, other multi-planar scanners, and the like. These two methods are as follows:

1. Line Tracing or Boundary Marking of Data Taken From Image Sections. In this method, line tracing or boundary marking or contouring of image data taken from various image sections are used to create "wire frame" graphic simulations of the contour margins of each section and thereby simulate image data in a three-dimensional fashion. Such wire frame simulations are usually rotated so that they can be

viewed from several perspectives to create a three-dimensional image. In some cases, the wire frame simulations are shaded to produce solids which can then be simulated in a three-dimensional fashion with associated simulation of light source views from various directions. The disadvantage of this technique is that the original image, from techniques such as CT, MRI, etc., is discarded once the wire frame tracings have been made. Valuable data with regard to the quality and features in the original image data are lost or not used. For example, this is somewhat like comparing a photograph of an object to a line tracing of an object. In essence, the original image is used to create another image which is a rough simulation of some features of the original image.

Examples of this method are disclosed in the following patents. U.S. Patent No. 4,791,934, entitled *Computer Tomography Assisted Stereotactic Surgery System and Method*, to Brunnett, discloses a two-dimensional "shadowgraph" comparison of two images to obtain an indication of the relative spacial orientation and position between the patient and a map. The actual CT data is discarded after rendering the images.

2. <u>Use of Original Image Data to Create a Three-Dimensional Solid</u>. In this particular method, image sections are combined to produce a three-dimensional reconstructed solid of the subject area or object. The original image data is not lost but there is no transparency; hence various structures within the subject area cannot be viewed in a three-dimensional manner in relationship to surrounding areas. Usually, the reconstructed solid form is processed in such a fashion that various two-dimensional surface sections can be viewed. Although this may be superior to standard two-dimensional imaging, there is still difficulty in viewing three-dimensional relationships of subject parts within the reconstructed solid. For example, if a computer simulation of the head with all its contents is reconstructed to produce a solid simulation, one initially has no more information than if they were viewing the head with the naked eye. Thus this kind of reconstruction does not present any more useful data than can be obtained by visual observation. In an attempt to overcome this difficulty, methods for producing computer sections along different planes have been done to "see" inside the solid. As can be appreciated

by those skilled in the art, two-dimensional sections from various angles can produce images which are themselves confusing in terms of anatomical relations.

An example of this method includes U.S. Patent No. 4,777,598, entitled *Image Processing Systems and Methods*, to Kellar, et al., which generates a three-dimensional reconstruction from two-dimensional slices. However, once the solid is rendered, one cannot see structures or features inside the solid. Also, the '598 patent does not disclose mixing of images generated from actual data with simulated graphics.

Other methods are utilized in the art for manipulating actual image data, however, these do not combine actual data image representations with simulated images of selected features of diagnostic, therapeutic, or surgical devices or body objects or features. Examples of such methods are disclosed in: U.S. Patent No. 4,259,725, entitled *Cursor Generator for Use in Computerized Tomography and Other Image Display Systems*, to Andrews, et al., which is addressed to overlaying a displayed image with another two-dimensional simple image, such as a pointer, arrow, star, circle, rectangle, and the like; and U.S. Patent No. 4,608,635, entitled *Method and Apparatus for Tomographic Diagnosis*, to Osterholm, which discloses a tomographic diagnosis system utilizing an apparatus which images the radiodensity of various regions of the body and compares actual images with predetermined images generated from actual patient data; and U.S. Patent No. 4,651,732, entitled *Three-Dimensional Light Guidance System for Invasive Procedures*, to Frederick, which discloses a three-dimensional guidance system which develops a line of light above a patient's body to indicate the entry point and path of an invasive instrument.

None of the methods or devices described above combine real or actual three-dimensional imaging data with simulations of features of actual structures or techniques to be employed pertaining to such structures. For example, the present invention can combine images representing actual data of a patient's tumor, and combine this image with simulations, such as tumor volume; treatment zones to treat the tumor, such as radiation implant zones; path of a probe to reach the tumor; and the like.

SUMMARY OF THE INVENTION
(DISCLOSURE OF THE INVENTION)

The present invention comprises an apparatus for displaying a combined three-dimensional representation. This apparatus comprises means for calling from storage and displaying in a two-dimensional representation, at least one of the selected actual features of an actual three-dimensional object, such as tumors, lesions, abscesses, or abnormalities; means for generating and displaying in a two-dimensional representation a graphic simulation of at least one associated three-dimensional feature (a feature or structure of the actual object, such as a transparent solid volume or wire frame structure, or a feature or structure of another object, such as a stereotactic frame, probe, probe trajectory, radiation implant, radiation zone resulting from a radiation implant, or radiation beam); and means for combining the graphic simulation display with the display of selected actual features as a composite image in a manner suitable for viewing. Useful imaging techniques include CT, NMR, PET, DSA, isotope imaging, and the like.

In the preferred embodiment, the composite image display allows for selection of a two-dimensional planar slice through the actual object and displaying the selected slice in combination with the three-dimensional graphic simulation two-dimensional display. This two-dimensional planar slice can be displayed at essentially any viewer determined perspective. Also in the preferred embodiment, the graphic simulation provides for the display of a volume above and/or below the planar slice.

The selected actual features and graphic simulations may be displayed in any form, including wire frame representations, transparent solid representations, relative transparencies, and multiple color representations.

The present invention further comprises a method for displaying a combined three-dimensional representation. This method comprises the following steps of:

a. imaging an actual three-dimensional object and storing the data;

b. calling from storage and displaying in a two-dimensional representation at least one selected actual feature of the actual object;

c. generating and displaying in a two-dimensional representation a graphic simulation of at least one associated three-dimensional feature; and

d. combining the graphic simulation display with the display of the selected actual feature in a manner suitable for viewing by a user.

The discussion above is applicable to the method of the invention.

It is a primary object to provide an apparatus and method for combining three-dimensional imaging data with simulated computer graphics for improved diagnostic, therapeutic, and surgical techniques and other clinical procedures.

It is another object to provide an apparatus and method for providing enhanced information about structures in the body to the diagnostician or surgeon.

An advantage of the apparatus and method of the invention is that it improves the utilization of scanning and imaging techniques and devices.

Other objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the specification, illustrate several embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purposes of

illustrating a preferred embodiment of the invention and are not to be construed as limiting the invention.

Fig. 1 is a photograph of a computer screen display of an actual CT image section or scan slice combined with a simulated stereotactic frame and a stereotactic surgical probe directed towards a tumor lesion within the confines of the head;

Fig. 2 is a photograph of a computer screen display of an enlarged image section of Fig. 1, showing a wire frame simulation of a tumor volume;

Fig. 3 is a photograph of a computer screen display of an enlarged image section of Fig. 1, showing a simulated wire frame and shading to present the tumor as a three-dimensional shell;

Fig. 4 is a photograph of a computer screen display of an actual scan image slice with simulated wire frame tumor volume above and below the slice and simulated stereotactic probes and radioactive seeds;

Fig. 5 is a photograph of a computer screen display of multiple views of actual scan image slices in relationship to other corresponding CT images and showing simulated radiation treatment zones within a simulated shell of the tumor volume;

Fig. 6 is a photograph of a computer screen display of an enlarged view of an image, such as shown in Fig. 5;

Fig. 7 is a photograph of a computer screen display of multiple views of an example of simulated tumor volumes within the confines of a brain and simulated radiation treatment zones;

Fig. 8 is a photograph of a computer screen display of a wire frame presentation of a stereotactic frame, a tumor, and a probe trajectory;

Fig. 9 is a photograph of three-dimensional simulation of a stereotactic frame and actual MRI images in frontal, saggital, and horizontal views using a whole brain voxel proportional method for simulated mapping of each voxel area of the brain viewed; and

Fig. 10 is a block diagram of the apparatus and method of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION (BEST MODES FOR CARRYING OUT THE INVENTION)

The present invention combines or overlays actual image representations with simulated wire frame or solid graphics such that the three-dimensional nature or features of structures or objects within a given area or region, *e.g.*, head, can be displayed and viewed in relationship to one another. The advantage of the present invention is that the original image data is not discarded to create the three-dimensional simulation, yet associated data is used to construct wire frame or solid contours of three-dimensional forms and structures within the area of interest.

With reference to Fig. 10, the apparatus and method of the invention provide for the following: (a) scanning, acquiring images, or imaging 10 an actual three-dimensional object (*e.g.*, brain), preferably with a multi-slice imaging technique (*e.g.*, from MRI, CT, DSA (Digital Subtraction Angiography), PET (Positron Emission Topography), and other isotope scanners) and storing 12 the data obtained; (b) calling from storage 12 and displaying 14 in a two-dimensional representation (*e.g.*, on a computer display screen or video monitor) a selected feature or structure (*e.g.*, tumor) of the actual object; (c) generating and displaying 14 in a two-dimensional representation (*e.g.*, on a computer display screen or video monitor) a graphic simulation of associated three-dimensional features or structure of the actual object or other objects; and (d) combining 14 the graphic simulation display with the display of the selected actual feature or structure in a composite image in a manner suitable for viewing by a user. The scanner 10 may be directly connected to the storage 12 and display 14 means, such that images are directly acquired, or images may be transferred to the storage 12 and display 14 means via tape, ethernet or camera. Digital data of images may be stored in the storage 12 and display 14 means, such as a computer memory. The digital data in the images is analyzed and displayed to define certain selected features or structures, or to outline the boundaries of certain features or structures. Similar data from other image sections are also analyzed and stored. These data are then utilized to create three-dimensional simulations of selected

features or structures, such as wire frame, solid, surface renditions, or transparent three-dimensional renditions. The images created thereby are then displayed with various originally obtained images, such as slices, to create a three-dimensional simulation of selected features or structures rendered in various three-dimensional manners, noted above, such that they can be seen in relationship to the actual CT, NMR or other scanning data. Various original scan data can be selectively displayed in relationship to the images created or simulated and rotated and manipulated in various ways. Images created, as noted above, can be further simulated in various manners to define graphical three-dimensional simulation of other objects (*e.g.*, stereotactic frame, probe, probe trajectories, radiation implants, and radiation zones, radiation and laser beams, and the like). Images created and stored can be recalled for further display.

As can be appreciated by those skilled in the art, the simulation can be of a feature of the actual object (*e.g.*, tumor volume or structure, or other sub-structures, such as blood vessels or ventricular systems within the brain or other body areas), or a feature of another object (stereotactic frame, probe, probe trajectories, radiation implants, and radiation zones resulting from proposed radiation implants), which combined with the image from the actual data provides an effective tool for the clinician. The features simulated can be represented as transparent solids, wire frame structures, in varying colors and transparencies, and combinations thereof, and other renditions, depending on the desired visual effect. As an example, a two-dimensional planar slice through the brain generated from actual data, can be combined with graphic simulation of a volumetric entity, such as a tumor, above and below the planar slice. The planar slice may be viewed at essentially any viewer determined perspective.

The apparatus and method of the invention preferably utilize the imaging methods and apparatus of U.S. Serial No. 07/290,316, entitled *Method and Apparatus for Video Presentation from a Variety of Scanner Imaging Sources*, to Tyrone L. Hardy, to generate more accurate images from actual data or actual data combined with known data (*e.g.*, brain maps), although other techniques for generating images from actual data could be utilized in the invention. The resulting images from the actual data is then combined with simulated graphics data to yield

three-dimensional information useful for diagnostic, therapeutic and surgical techniques and other clinical procedures. The graphics simulations can be accomplished by methods well known in the art using standard three-dimensional transformation algorithms or methods, or by the methods described in patent application Serial No. 07/290,316. The position of wire frame or other renditions of structures or features within any image is transposed to the actual image by these techniques.

In the preferred embodiment, the computer is connected to a video printer, camera, magnetic tape, ethernet image acquisition interface, or the like, so that black and white or preferably color copies or photos can be printed whenever the viewer desires to make a record of the procedure or images obtained. Also in the preferred embodiment, all resulting images are stored (*e.g.*, on magnetic or video tape) so that an archive record can be maintained by the clinician.

The preferred apparatus and method of the invention provide for one or more of the following features: acquisition of images directly from any scanner; pseudo-coloring; edge detection; pixel analysis; precise volume and point-to-point measurements; perspective viewing of multiple image sections; and Flicker-Frame-Overlay for transparency viewing (an image display technique in which the viewer of a computer video monitor screen is presented with alternating frames of different images or images from different sources in a rapidly alternating manner such that images from two different sources appear to be transparent to one another, *i.e.*, two images are presented in the same frame of reference for comparison). For medical applications, the invention may provide for one or more of the following features: preoperative planning and simulation of the operative procedure; and tailored graphic scaling of brain maps, probe tracks, electrophysiological maps, and volumetric and coordinate measurements to patient images. For stereotactic techniques, the invention may provide for one or more of the following features: probe coordinate determination; probe trajectory simulation; anatomical or electrophysiological diencephalic mapping; whole brain mapping (*e.g.*, Talairach/Tournoux); three-dimensional brachytherapy optimization; three-dimensional laser localization for open craniotomy, such as disclosed in co-pending application Serial No. 07,428,242, entitled *Three Dimensional Laser Localization Apparatus and Method for Stereotactic Diagnoses or Surgery*, to Tyrone L. Hardy, et al.; three-

dimensional microsurgical simulation; three-dimensional angiography; three-dimensional radiosurgery; and three-dimensional imaging and graphic simulation of the stereotactic frame. The mapping systems can be individually scaled and superimposed over any patient's image for specific mapping purposes. For probe simulation, the invention provides for rapid probe coordinate determination and various simulations of the probe's position; perspective; a graphic simulation of the probe as it travels through a series of stacked slices; a three-way graphic view of the probe on combinations of sagittal, frontal and horizontal images from various scanners; and three-dimensional graphic simulation of the probe, pointing indicators, or the like, within a stereotactic frame. Throughout the specification and claims, the term "probe" includes other pointing indicators, such as laser beams, X-ray or radiation beams, other beams, trajectories, and the like.

Reference is now made to the drawings which illustrate photographs of actual computer screen displays of actual imaging data combined with simulated graphics such as a stereotactic frame, probe and probe trajectories, radiation implants, wire frame, solids, shaded volumes, and shells. The icons and numbers shown in the photographs represent computer graphics control symbols. Although the Figures show black and white photographs, the computer graphics displays are preferably in varying colors so that the information can be more readily discerned.

Fig. 1 shows an actual CT scan planar slice simulated within a stereotactic frame with a stereotactic surgical probe directed toward a tumor lesion within the confines of the head. Figs. 2 and 3 are magnified or enlarged views of the image section shown in Fig. 1. Fig. 2 is a three-dimensional wire frame simulation of a tumor volume and structure relative to the image slice, and Fig. 3 shows wire frame simulation shading to present the tumor as a three-dimensional shell. In Fig. 3, the wire frame simulation of the tumor within the confines of the brain has been shaded such that it appears as a shell.

As can be seen by the drawings, by using the method and apparatus of the present invention, one can choose a feature of structure of interest within the confines of the imaged area and simulate that structure in wire frame or solid form showing its relationship to the image slices. The relationship of the structure of interest to the surrounding

anatomical areas is enhanced. Images created in this fashion can be viewed from a number of perspectives such that simulations of a structure above and below an image slice can be viewed. An important feature of this method of the present invention is the creation of image sections having true transparency. That is, by example in Figs. 2 and 3, the three-dimensional construction of the tumor volume and structure can be seen above and below the image slice. By analogy, this is somewhat like having a painting on a very fine mesh screen by which one can simultaneously see through the screen to see objects behind the screen, yet also be able to see the painting on the screen.

Fig. 4 is another example of a three-dimensional wire frame simulation of a tumor lesion within the confines of the brain viewed in relation to an actual CT scan image slice. In this particular display, again the tumor volume and structure above and below the image slice can be viewed. Vertical stereotactic surgical probes are simulated to show possible trajectories to target areas within the confines of the tumor volume and structure. The bright white spheres on the ends of the simulated probes simulate the position of radioisotope seeds placed within the confines of the tumor as a therapeutic treatment modality. The larger three-dimensional balls or spheres within the confines of the three-dimensional wire frame simulation of the tumor simulates the kill zones or therapeutic zones for some additional isotope seeds. The radioisotope seeds are present at the center of the spheres. This Figure is an example of how multiple areas of interest can be graphically simulated relative to an actual image slice. The surgical or therapeutic techniques can be optimized by varying the position of the radioisotope seeds and by varying the type of radioisotopes, which can be simulated prior to employing the desired procedures.

Fig. 5 shows multiple views of the same three-dimensional tumor volume and structure relative to another corresponding CT image showing three-dimensional simulated radiation treatment zones within shell and solid renditions of the tumor volume and structure. The simulated radiation treatment zones (dark areas) which extend beyond the confines of the simulated tumor volume and structure (light areas) can be readily discerned. For demonstration purposes, an enlarged computer rendition is shown in Fig. 6. Fig. 7 is another rendition showing radiation treatment zones within the wire frame simulation of the tumor volume and

structure and where treatment zones extend beyond the confines of the tumor. Such simulated radiation zones around each seed are used in the preliminary stages of radiation treatment optimization before final dose calculations are performed. The grids (*e.g.*, 1 cm square) can be used as a measuring aid. This particular method can be used to optimize treatment of tumor lesions, that is the goal is to have the radiation treatment zones touch the margins of the tumor volume and structure, but not break out substantially beyond the margins.

This combining of actual image data with graphics simulation of related three-dimensional entities and image transparency can be used to simulate other therapeutic diagnostic and relational properties. For example, Fig. 8 illustrates a wire frame presentation of a stereotactic frame, a tumor within the confines of the brain and the simulation of a therapeutic probe's trajectory toward a target area within the confines of the tumor.

Fig. 9 is another example showing a three-dimensional simulation of MRI images in frontal, saggital, and horizontal views using a whole brain voxel proportional method for mapping each voxel area of the brain viewed. Various image slices can be presented in a single fashion or in various combinations to study specific areas of interest. Although this photograph shows orthogonal images, images at other angles and in varying combinations may be utilized depending upon the area of interest. This method can also be used, as stated before, to show the three-dimensional relationships of various structures within the confines of the brain in relationship to other structures. For example, the ventricular system, certain blood vessels, tumors, and other structural areas, lesions, abscesses, abnormalities of the brain (or other areas of the body), can be simulated in their three-dimensional relationships to other brain (or other body) areas.

In the drawings, actual image data points are utilized in the construction of the wire frame renditions. The lines connect these actual data points to complete the frame.

Although the drawings all show actual imaging data of brains in combination with a stereotactic frame, the invention is not limited to heads or brains, but could be utilized on any body portion wherein

accurate and detailed information is desired to be combined with simulations. For example, the apparatus and method of the invention could be useful in the placement of objects into the body, such as blood vessels during an angiogram, radioisotope therapy, biopsies, radiosurgery, the optimization of laser or stereotactic positioning, surgical or diagnostic methods for other body parts with a frame system suitable for such body parts (*e.g.*, cylindrical coordinate system for a spinal stereotactic frame, or the like). The present invention provides for a high degree of accuracy and one can tell precisely what specific anatomical areas are within the simulated regions. The apparatus of the invention is also useful in conjunction with attachments to frames, such as microscopes, lasers, robots, other stereotactic devices or pointers, and radiation delivery systems.

Although the invention has been described with reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents.

CLAIMS

What is claimed is:

1. An apparatus for displaying a combined three-dimensional representation comprising:

means for calling from storage and displaying in a two-dimensional representation, at least one of the selected actual features of an actual three-dimensional object;

means for generating and displaying in a two-dimensional representation, a graphic simulation of at least one associated three-dimensional feature; and

means for combining said graphic simulation display with said display of selected actual features as a composite image in a manner suitable for viewing by a user.

2. The invention of claim 1 wherein said two-dimensional representation display is obtained from at least one imaging technique selected from CT, NMR, PET, DSA, and isotope imaging.

3. The invention of claim 1 wherein said graphic simulation of said associated three-dimensional feature comprises a feature or structure of the actual object.

4. The invention of claim 3 wherein said feature of the actual object comprises a volume.

5. The invention of claim 4 wherein the volume is represented as a transparent solid.

6. The invention of claim 4 wherein the volume is represented in a wire frame structure.

7. The invention of claim 1 wherein said graphic simulation of said associated three-dimensional feature comprises a feature or structure of another object.

8. The invention of claim 7 wherein the other object comprises at least one member selected from the group consisting of stereotactic frames, probes, probe trajectories, radiation implants, radiation zones resulting from radiation implants, and radiation beams.

9. The invention of claim 1 wherein the actual object comprises at least one structure in the body selected from the group consisting of tumors, lesions, abscesses, and abnormalities.

10. The invention of claim 1 wherein said displaying means for said selected actual features comprises means for selecting a two-dimensional planar slice through the actual object and means for displaying the selected slice in combination with said three-dimensional graphic simulation two-dimensional display.

11. The invention of claim 10 wherein said two-dimensional planar slice selecting and displaying means comprises means for selecting and displaying the slice at essentially any viewer determined perspective.

12. The invention of claim 10 wherein said graphic simulation of said associated three-dimensional feature comprises a volume in at least one region of above and below said planar slice.

13. The invention of claim 1 wherein said displaying means for said selected actual features comprises means for displaying a wire frame representation of said selected features.

14. The invention of claim 1 wherein said displaying means for said selected actual features comprises means for displaying a transparent solid representation of said selected features.

15. The invention of claim 1 wherein said graphic simulation displaying means comprises means for generating a multiple color representation thereof.

16. The invention of claim 1 wherein said displaying means for said selected actual features comprises means for generating a multiple color representation thereof.

17. The invention of claim 1 further comprising means controllable by a user for selecting aspects of the selected actual features display for relative transparency.

18. The invention of claim 1 further comprising means controllable by a user for selecting aspects of the graphic simulation display for relative transparency.

19. A method for displaying a combined three-dimensional representation comprising the following steps of:

a) imaging an actual three-dimensional object and storing the data;

b) calling from storage and displaying in a two-dimensional representation at least one selected actual feature of the actual object;

c) generating and displaying in a two-dimensional representation a graphic simulation of at least one associated three-dimensional feature; and

d) combining the graphic simulation display with the display of the selected actual feature in a manner suitable for viewing by a user.

20. The invention of claim 19 wherein said graphic simulation of said associated three-dimensional feature comprises a feature or structure of the actual object.

21. The invention of claim 20 wherein said feature of the actual object comprises a volume.

22. The invention of claim 21 wherein the volume is represented as a transparent solid.

23. The invention of claim 21 wherein the volume is represented in a wire frame structure.

24. The invention of claim 19 wherein said graphic simulation of said associated three-dimensional feature comprises a feature or structure of another object.

25. The invention of claim 24 wherein the other object comprises at least one member selected from the group consisting of stereotactic frames, probes, probe trajectories, radiation implants, radiation zones resulting from radiation implants, and radiation beams.

26. The invention of claim 19 wherein the actual object comprises at least one structure in the body selected from the group consisting of tumors, lesions, abscesses, and abnormalities.

27. The invention of claim 19 wherein said displaying means for said selected actual features comprises means for selecting a two-dimensional planar slice through the actual object and means for displaying the selected slice in combination with said three-dimensional graphic simulation two-dimensional display.

28. The invention of claim 27 wherein said two-dimensional planar slice selecting and displaying means comprises means for selecting and displaying the slice at essentially any viewer determined perspective.

29. The invention of claim 27 wherein said graphic simulation of said associated three-dimensional feature comprises a volume or structure in at least one region of above and below said planar slice.

30. The invention of claim 19 wherein said displaying means for said selected actual features comprises means for displaying a wire frame representation of said selected features.

31. The invention of claim 19 wherein said displaying means for said selected actual features comprises means for displaying a transparent solid representation of said selected features.

32. The invention of claim 19 wherein said graphic simulation displaying means comprises means for generating a multiple color representation thereof.

33. The invention of claim 19 wherein said displaying means for said selected actual features comprises means for generating a multiple color representation thereof.

34. The invention of claim 19 further comprising means controllable by a user for selecting aspects of the selected actual features display for relative transparency.

35. The invention of claim 19 further comprising means controllable by a user for selecting aspects of the graphic simulation display for relative transparency.

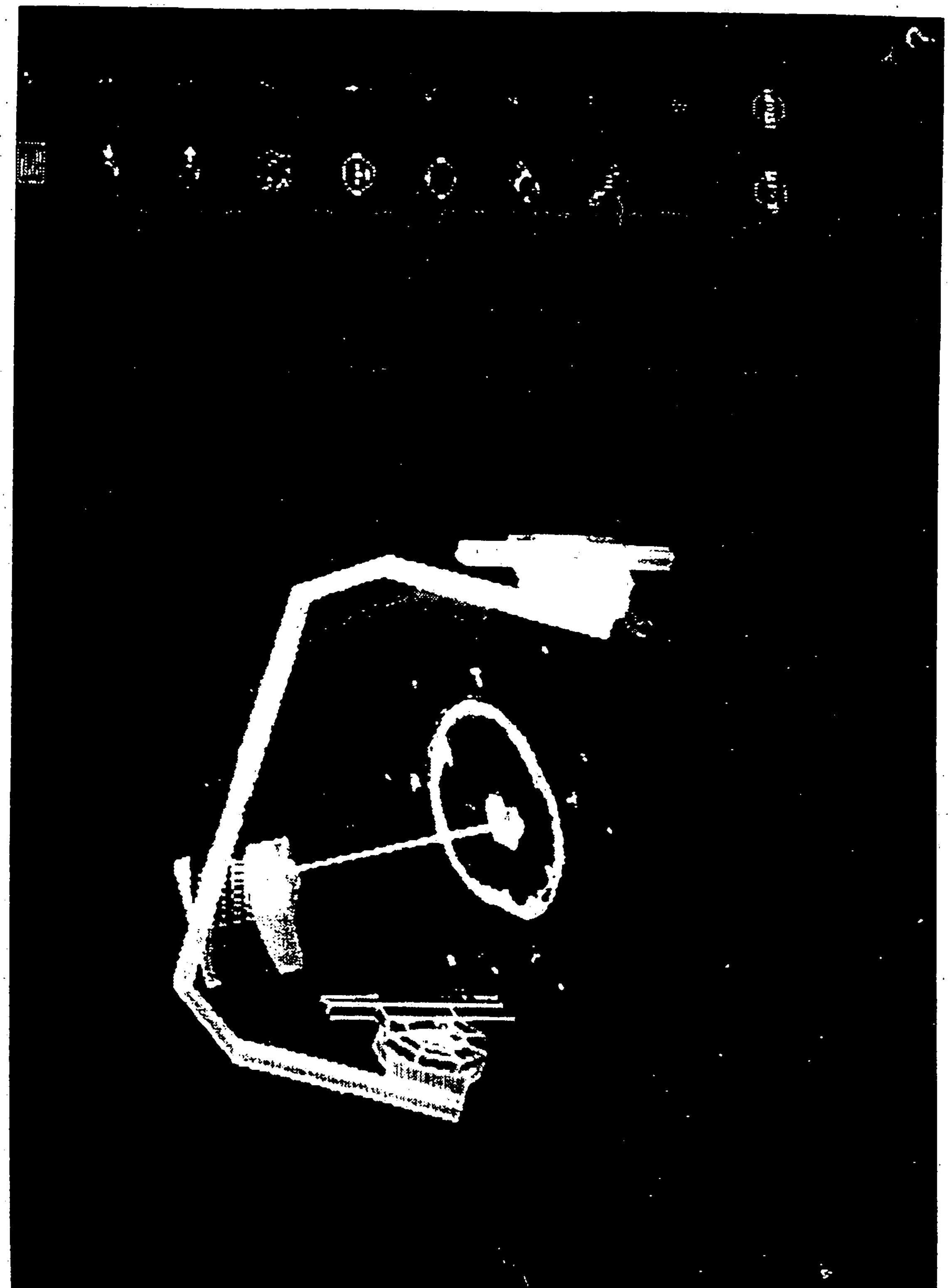

FIG. 1

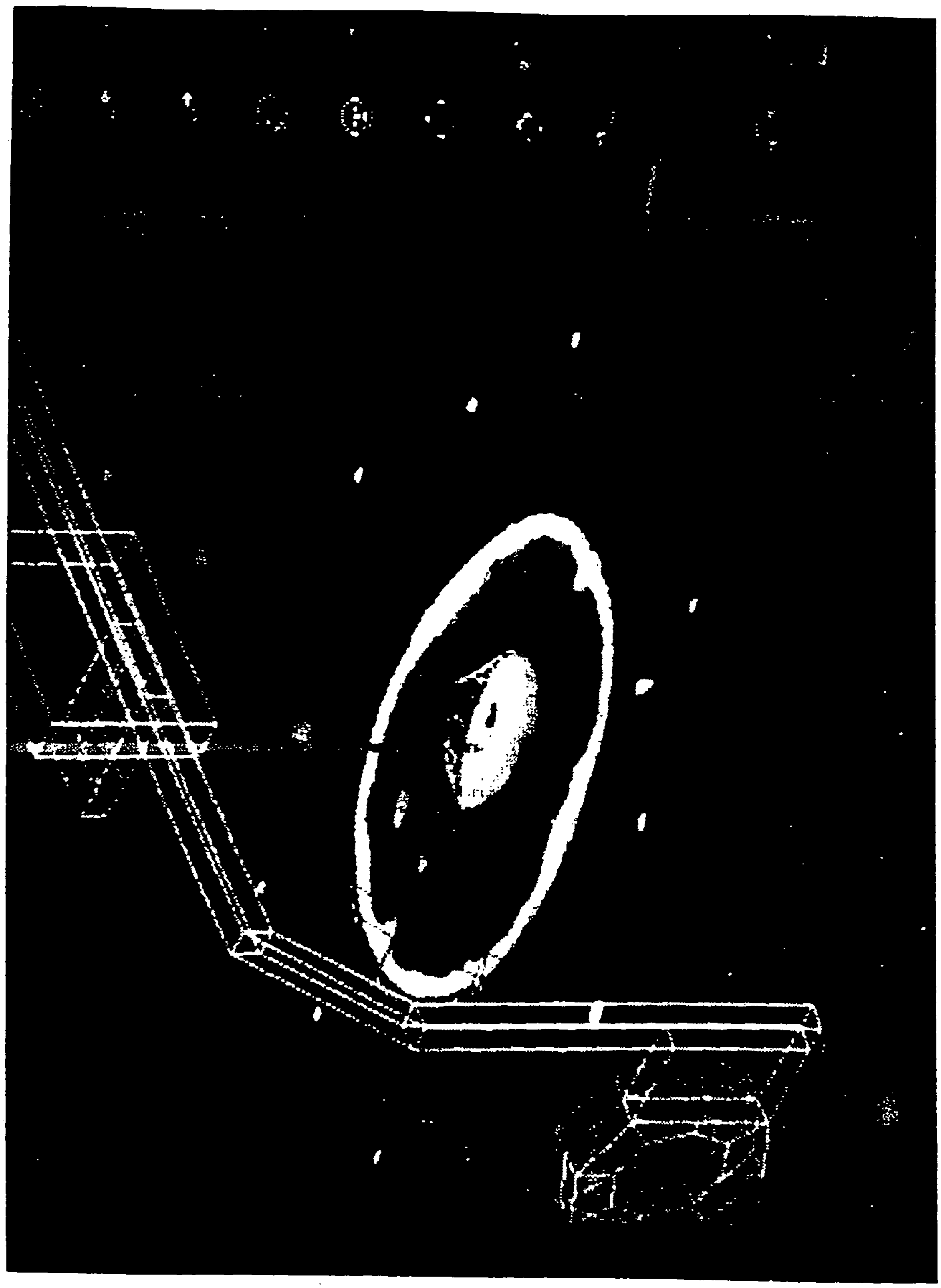

FIG. 2

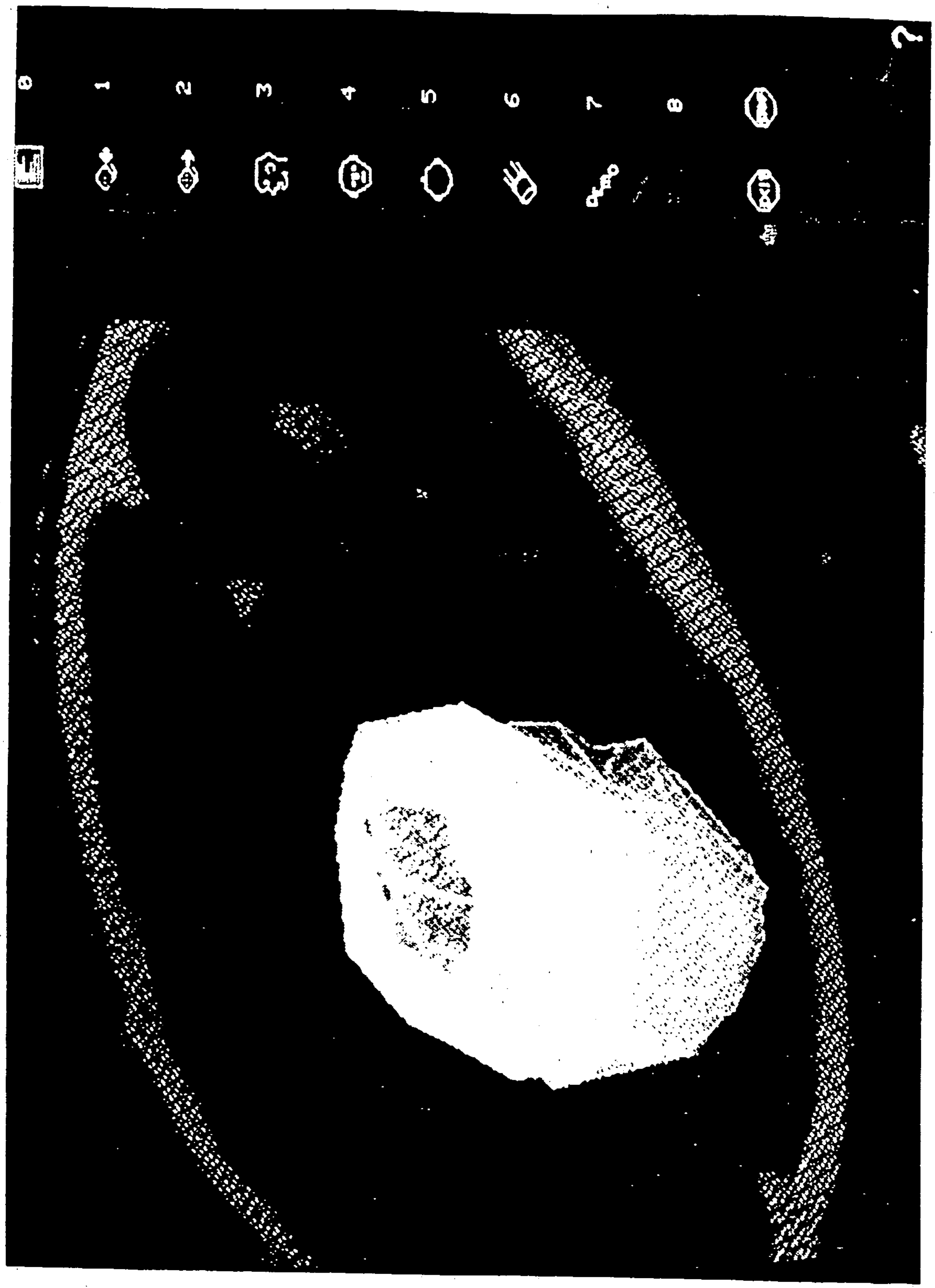

FIG. 3

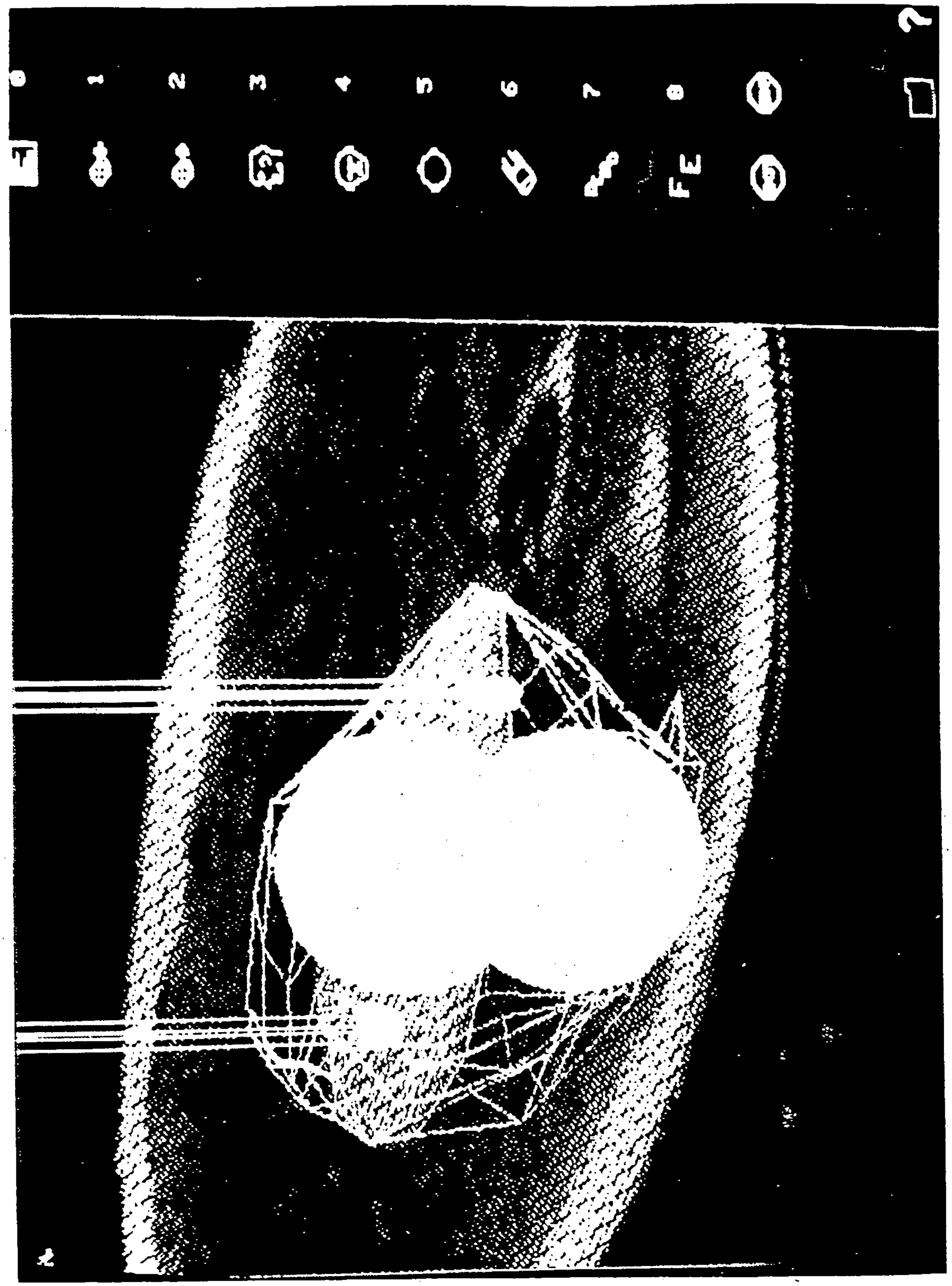

FIG. 4

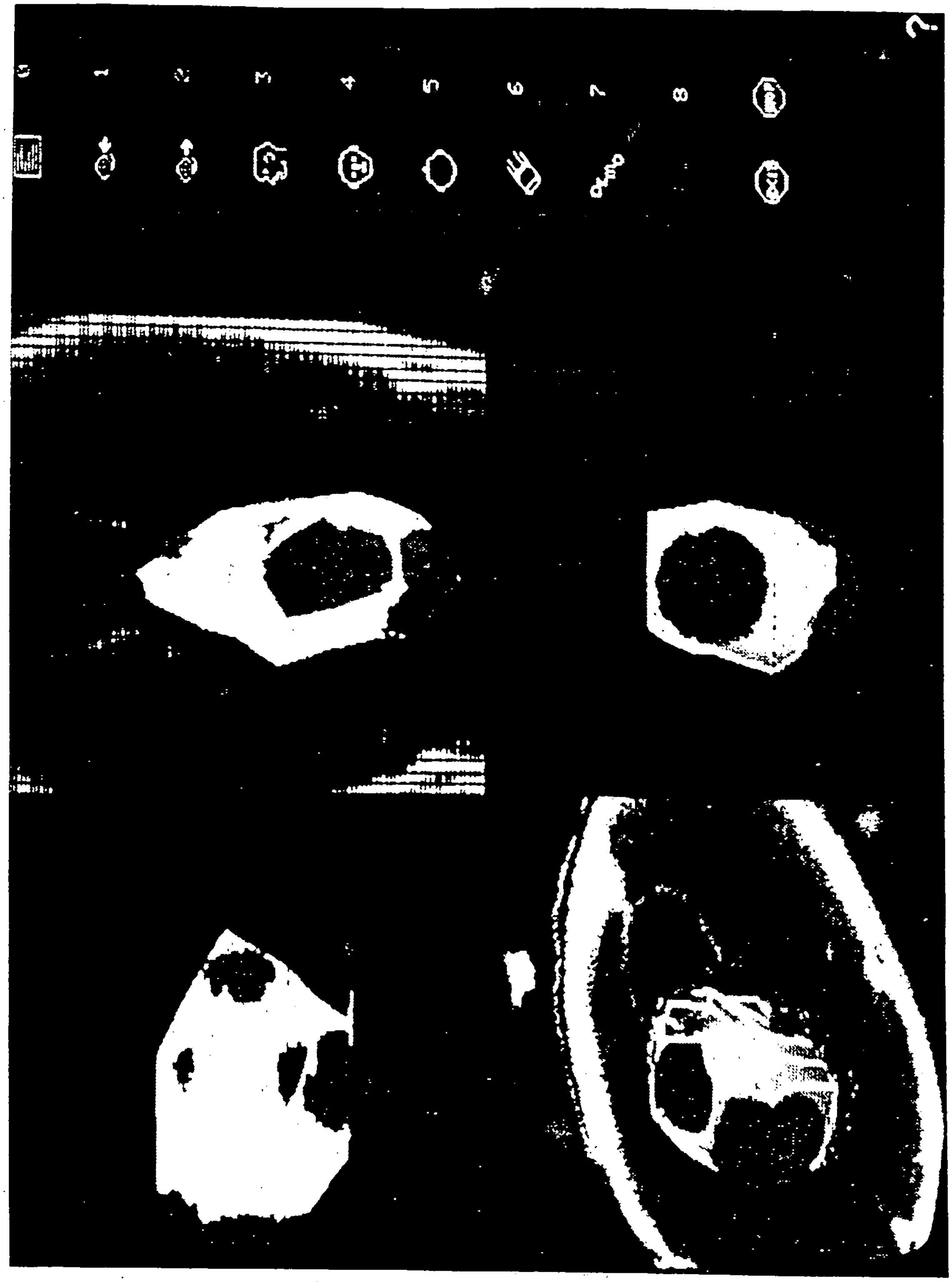

FIG. 5

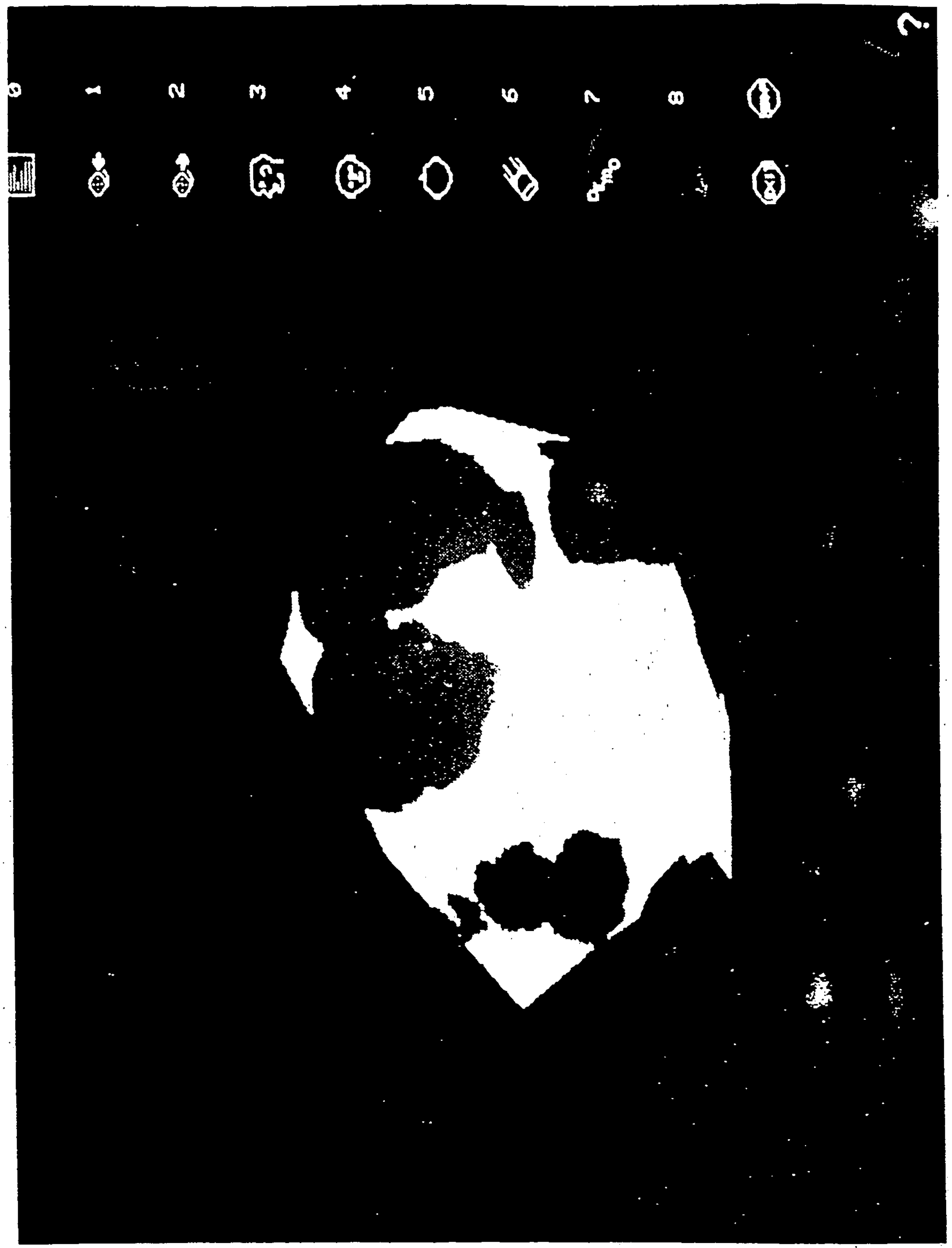

FIG. 6

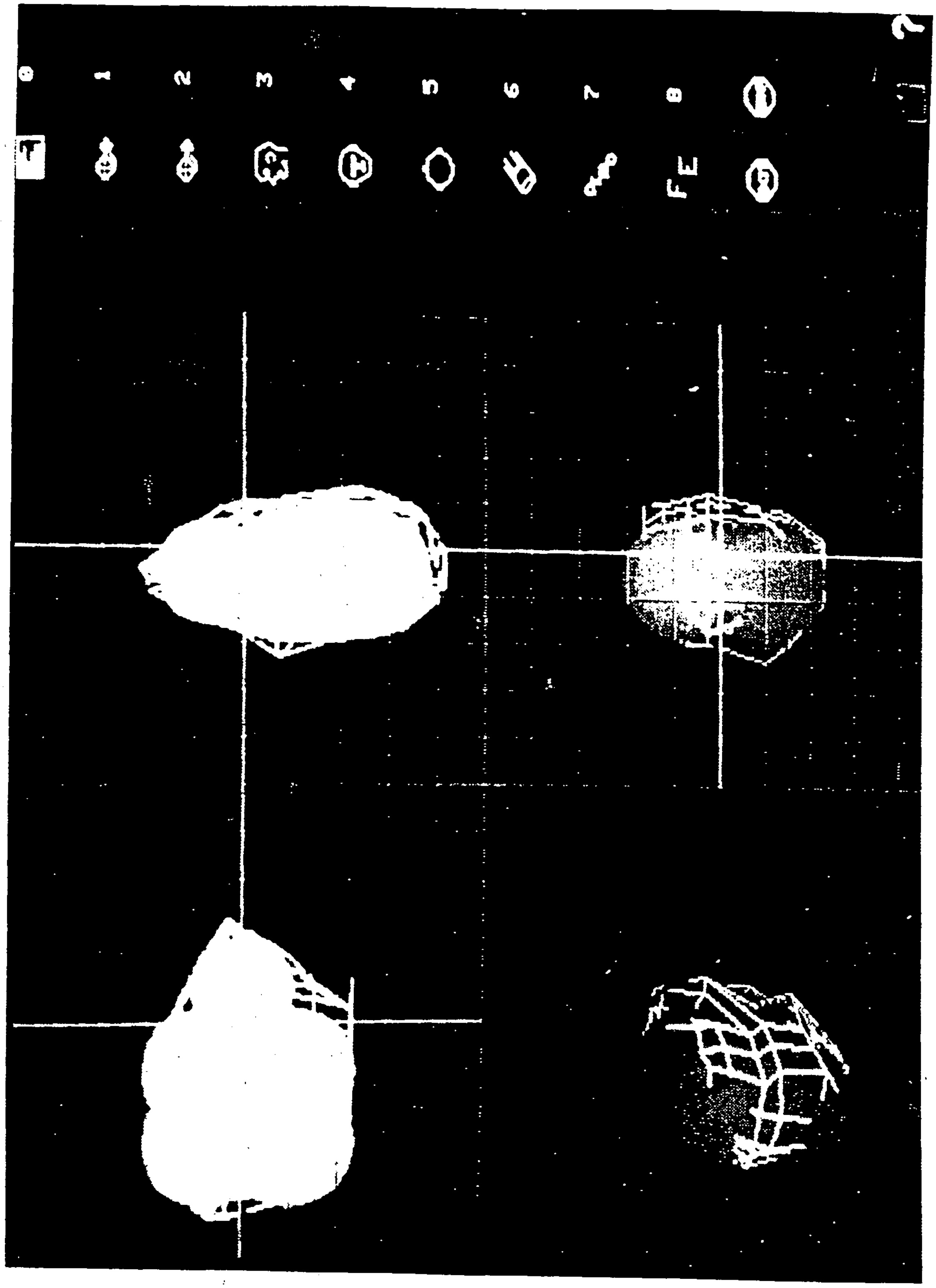

FIG. 7

SUBSTITUTE SHEET

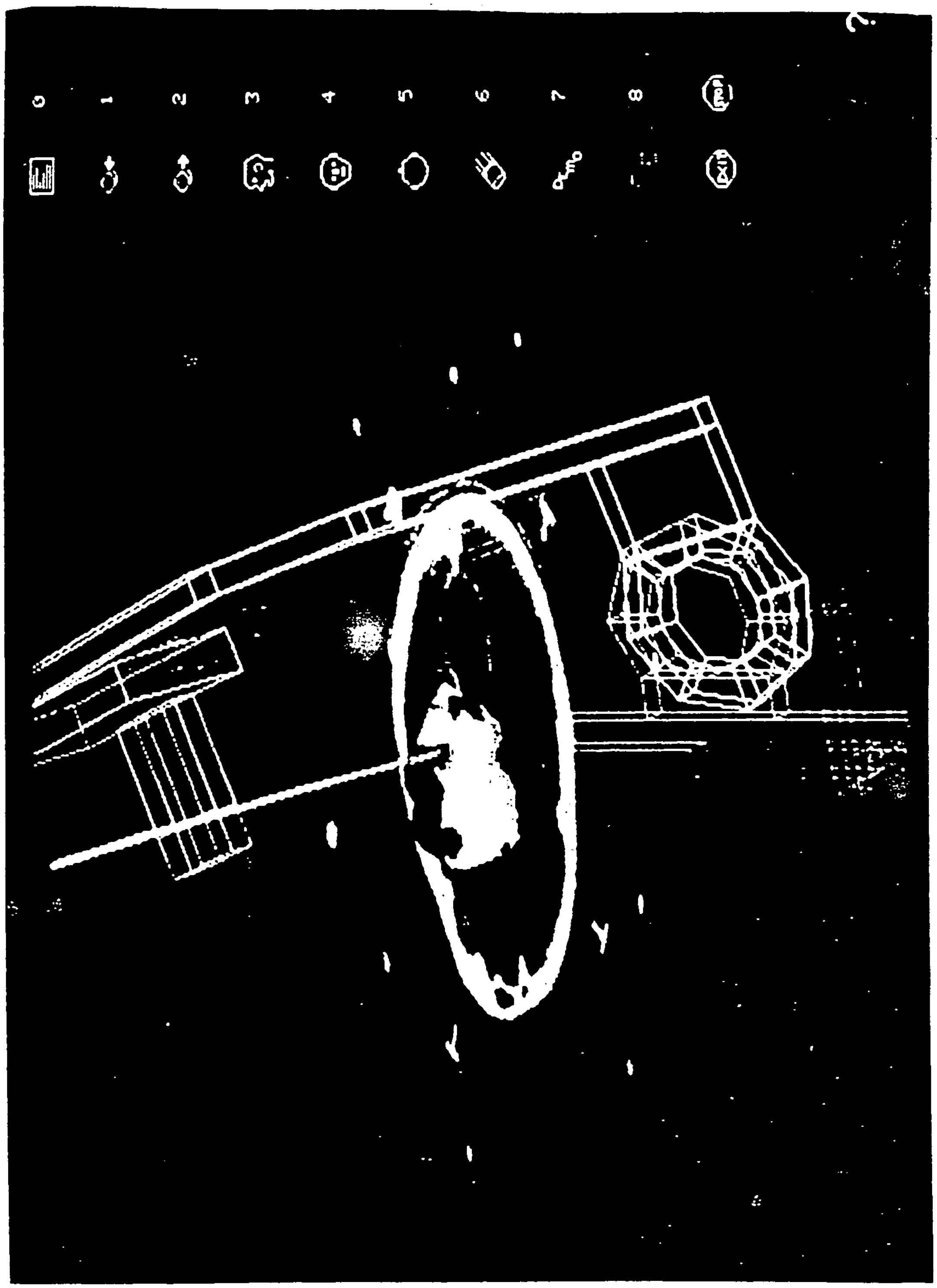

FIG. 8

SUBSTITUTE SHEET

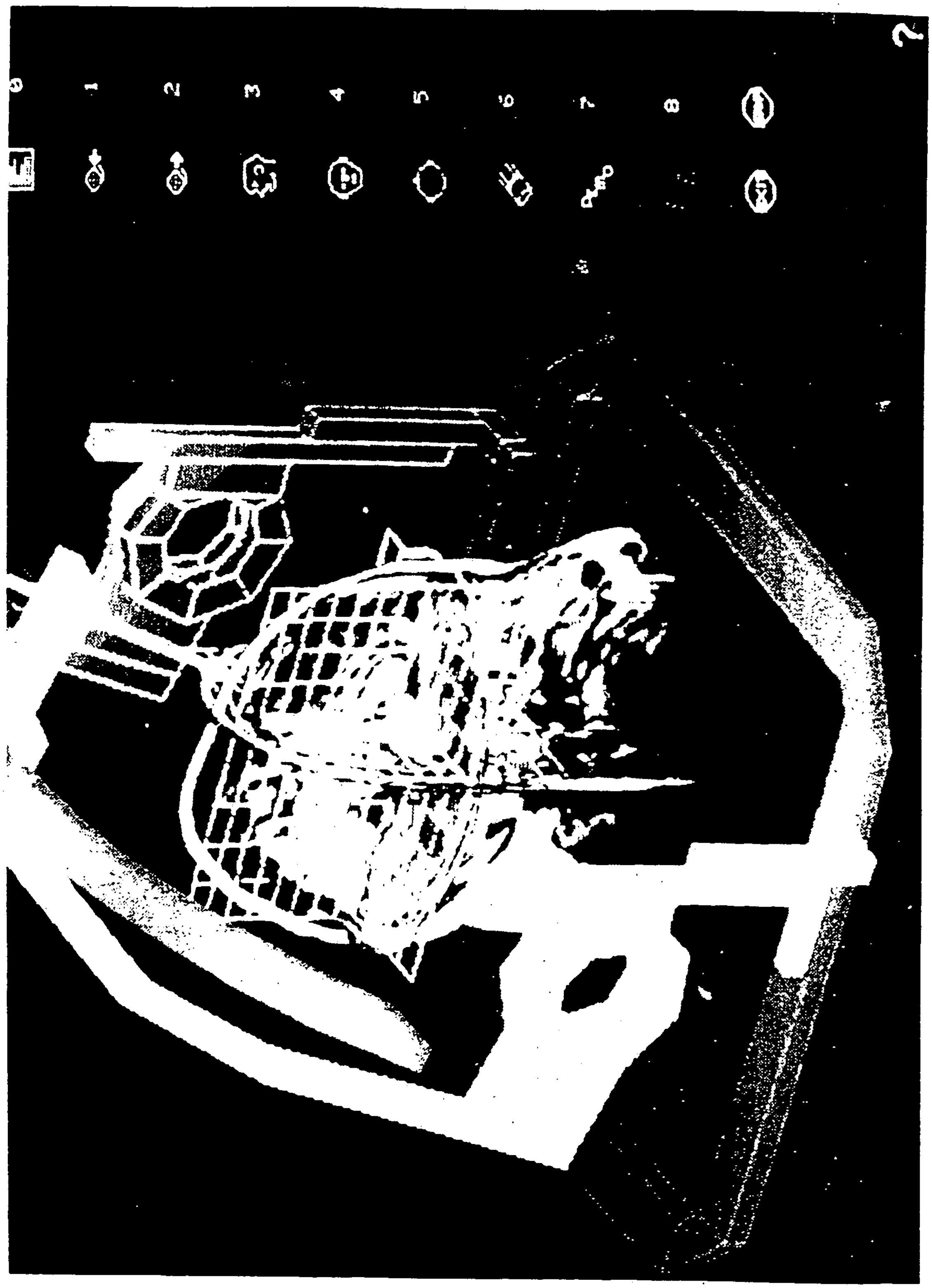

FIG. 9

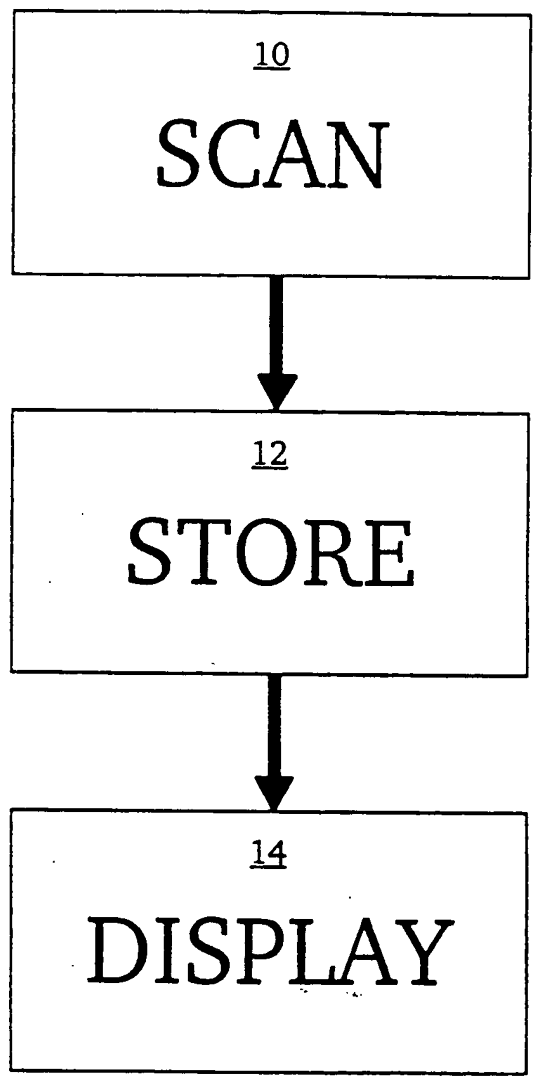

FIG. 10